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THE JOURNAL
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THE SPECTROSCOPIC ORBITS AND DIMENSIONS OF THE ECLIPSING VARIABLES *U OPHIUCHI*, *RS VULPECULAE* AND *TW DRACONIS*

BY J. S. PLASKETT

Introduction

In determining the orbital elements of a spectroscopic binary from a series of measurements of the radial velocity, we can usually obtain the period, the eccentricity of the relative orbit, the maximum orbital velocity, the velocity of the centre of mass of the system, and the longitude and time of periastron.

The inclination of the plane of the orbit to the plane tangent to the celestial sphere is indeterminable and consequently, though formulae are available giving the semi-axis major and the mass, these both appear as functions of the sine of the inclination and their actual values must remain unknown so long as the inclination is unknown. Further, in respect to the expression for the mass of the system, it appears as a function of the ratio of the masses of the two bodies and unless this is known, which is the case only in the comparatively few instances when the spectra of both components are present, neither the mass of each nor the total mass of the system, always appearing with the function of the inclination attached, can be determined.

It is only in two special cases that the inclination can be obtained, in visual binaries whose orbital elements have been determined and in eclipsing (Algol) variables of which the light curve is accurately known.

In the case of visual binaries, with the inclination and the relative radial velocities of the two components known, we can evidently obtain the masses, the dimensions of the orbit, and the parallax, but not the diameters and densities of the two stars.

In the other case, the one under consideration, where the spectroscopic binary revolves in a plane so nearly in the line of sight that the stars mutually eclipse one another twice in the period, then, if an accurate light curve is available, not only the inclination but the relative dimensions of the two bodies in terms of the major axis of the system can be determined. When, in addition, both spectra can be measured, complete information can be obtained about the actual diameters, masses, densities, and distance apart of the two bodies. This is of importance in view of the small number of stars for which we have such data.

In the three orbits to be discussed here, both spectra have been observed in *U Ophiuchi* and *RS Vulpeculae* in which consequently complete dimensions are available. With *TW Draconis* the second spectrum is invisible and the dimensions in this case must depend upon an assumption as to the ratio of the masses of the two bodies.

U Ophiuchi.

The eclipsing variable *U Ophiuchi* (α, 17h 11.4m; δ, +1° 19′ 1900, Vis. Mag. 5.7, Spectral Type B9) was placed under observation for radial velocity on March 19, 1919, and observations were continued until June 4. In all 18 plates were obtained, of which 14 were used in determining the spectroscopic elements. The remaining four plates were so near the minimum or zero velocity in the orbit that the doubled lines could not be separated, with the result that their velocities are unreliable and were not used.

The lines of the spectrum are rather wide and are diffuse and faint, lacking in contrast, this latter probably due to the superposition of the continuous spectrum of the one star on the absorption lines of the other. One plate, No. 1983, obtained at principal minimum shows the spectrum with single lines. This spectrum is principally but not wholly, as it is only a partial eclipse, of the fainter star, and hence gives a truer idea of the character and type. From this spectrum the type should be classed as B5 but is rather

abnormal in the breadth of the hydrogen lines. In all nine doubled lines have been measured: Hγ, Hδ; He 4472, 4388, 4144, 4026; C 4267; Mg 4481; Ca, K, 3934. Owing to the lack of contrast and the diffuseness of the lines, the measures are difficult and necessarily not of very high accuracy. In many cases some of the lines of the weaker spectrum could only be recognized and bisected by their showing a faint lightening of the spectrum on each side of the wire. Nevertheless, I believe the measures are reliable, as there is fair interagreement among the values for the different lines, and the general dimensions of the system are substantially correct.

TABLE I—OBSERVATIONS OF *U OPHIUCHI*.

Plate Number	Date 1919	Julian Date	Phase	Velocity		No. of Lines	Residuals O-C.	
				Brighter	Fainter		Brighter	Fainter
1745	Apr. 2	2,051.022	0.362	−196.9	+179.3	8	− 9.7	− 9.1
1776	" 7	2,056.974	1.282	+148.4	−222.6	8	−19.2	− 7.3
1805	" 13	2,062.973	0.572	−156.7	+159.3	7	+ 6.0	− 1.2
1808	" 14	2,063.019	0.618	−148.2	+128.8	9	− 4.4	−10.2
1905	" 28	2,077.935	0.438	−174.7	+215.4	8	+16.2	+22.8
1911	" 29	2,078.972	1.475	+139.1	−150.2	8	+24.7	+ 4.5
1938	May 3	2,082.876	0.347	−194.2	+194.2	8	− 9.5	+ 8.6
1952	" 4	2,083.866	1.337	+149.0	−194.8	8	−12.3	+13.3
1983	" 6	2,085.885	0.000		− 26.1	6	+14.6	+14.6
2009	" 19	2,098.884	1.259	+181.7	−216.2	8	+13.4	− 0.1
2053	" 30	2,109.911	0.544	−170.4	+174.3	6	+ 1.6	+ 3.1
2072	June 2	2,112.874	0.152	−118.4	+ 73.7	6	− 7.3	−28.1
2084	" 3	2,113.870	1.148	+155.1	−201.1	8	+ 1.9	− 2.1
2097	" 4	2,114.880	0.481	−187.8	+193.8	6	− 1.3	+ 6.1

In the above table the first three columns give the plate number, the date and Julian date of the observations. The fourth column gives the phase from primary minimum of the photometric orbit computed from the initial phase J.D. 2,418,026.703 with the period 1.6773476 days. The fifth and sixth columns give the observed velocities and the eighth and ninth the residuals from the final orbit of the brighter and fainter components respectively, while the seventh column contains the number of doubled lines measured on each plate, with the exception of plate 1983 on which six single lines were measured.

As the photometric orbit does not show any ellipticity and as the observations seem to follow sine curves as closely as can be expected, the orbit was assumed to be circular and consequently only K, the half amplitude, and γ, the velocity of the system, remain to be determined. From smooth curves drawn through the observations K_b was assumed 182.0 km., K_f 210.0 km. and γ, −12.0 km.

The velocity at any phase θ is given by $V=\gamma+K \sin \theta$ and to apply least squares corrections we have $\delta V=\delta\gamma+\delta K \sin \theta$.

The least squares correction gives the final elements

$$K_b = 179.8 \quad \pm 2.70 \text{ km.}$$
$$K_f = 204.6 \quad \pm 2.70 \text{ km.}$$
$$K = -11.5 \quad \pm 1.88 \text{ km.}$$

while the probable error of a single plate for each spectrum was the same and equal to ± 8.3 km. Considering the character of the spectrum and the difficulty of measurement, these results are satisfactory, the uncertainty of K and consequently of the dimensions of the system being only slightly over one per cent.

Applying these values by the well known formulae we have

$$a_b \sin i = 4{,}147{,}000 \text{ km}$$
$$a_f \sin i = 4{,}718{,}000 \text{ km}$$
$$(m_b + m_f)\sin^3 i = 9.890 \odot$$

In Shapley's photometric orbit* three solutions are obtained, two assuming uniformly illuminated discs and a third postulating darkening towards the limb. Shapley's second and third solutions are applied here, one uniform, one darkened. These give inclinations of 85° 42′ and 83° 58′, respectively, and make the radius of each star 0.252 of the semi-axis of the relative orbit in each solution. The dimensions, masses and densities of the system at once follow.

	Uniform	*Darkened*
a semi axis relative orbit	8,890,000	8,915,000
a_b semi axis brighter star	4,158,000	4,170,000
a in terms of radius of sun	12.78	12.82
a_b in terms of radius of sun	5.84	5.86
r_b radius brighter star	3.22	3.23
r_f radius fainter star	3.22	3.23
m_b mass brighter star	5.31	5.36
m_f mass fainter star	4.66	4.71
ρ_b density brighter star	0.20	0.18
ρ_f density fainter star	0.18	0.16

The volumes of the stars are computed assuming the elliptical forms given by the photometric orbit and

Volume brighter star	26.28	29.07
Volume fainter star	26.28	29.07
And the total surface area of both	18.88	19.62

*Contributions from Princeton Observatory, No. 3, p. 84.

If we assume the surface intensity of a B5 star to be −2.5 magnitudes*, the sun's absolute magnitude to be 4.86, the absolute magnitude of the brighter component of *U Ophiuchi* whose apparent magnitude is 6.35, is −0.19 and hence the parallax is 0″.0049.

A graph showing the sine curves for the two components with the velocities represented by open circles is shown in Fig. 1.

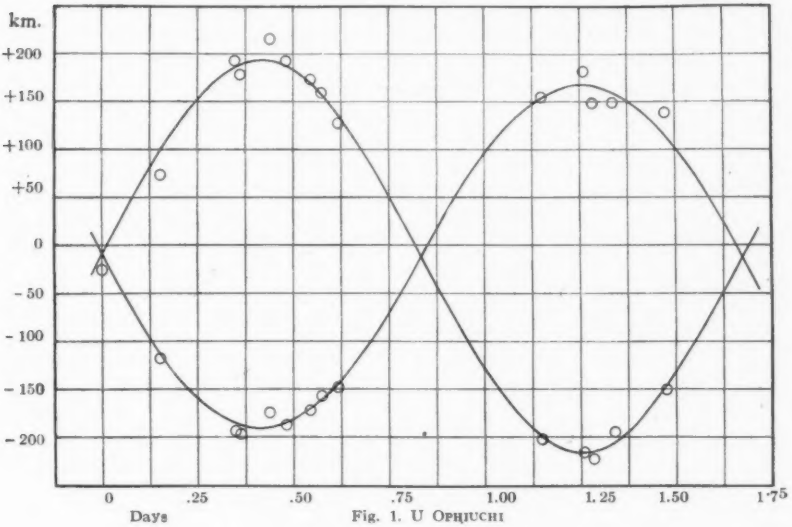


Fig. 1. U Ophiuchi

RS Vulpeculae.

The eclipsing variable *RS Vulpeculae* (α, 19h 13.4m, δ, +22 16′, 1900, Type A, Vis. Mag. 7.35) was placed under observation April 26, 1919, and the last plate used in the principal orbit was obtained on July 20, 1919. A fine-grained Seed 23 plate was obtained on July 30 and used for the second spectrum. Fourteen plates were obtained in this interval, all of which have been measured and used. The spectrum is of Type B8 instead of A and the magnitude as judged by comparison with *U Coronae* and *TW Draconis* appears considerably brighter than given by Nijland or Stewart.

Astrophysical Journal, **40**, p. 415, 1914.

This binary is especially interesting on account of the great disparity in size of the two components, the fainter star being five times the diameter of the brighter and nine-tenths as bright. It would consequently be expected, when the two stars are of nearly equal brightness,that the second spectrum would be plainly visible, but it can only be seen and measured with great difficulty and it is estimated to be of only about one-fourth the intensity of the brighter spectrum. Nevertheless, it was measured on six plates and although the residuals are in some cases rather large, the probable error of the measures of the second spectrum on a single plate being ±8.1 km., the lines and plates are in fair interagreement. Con-

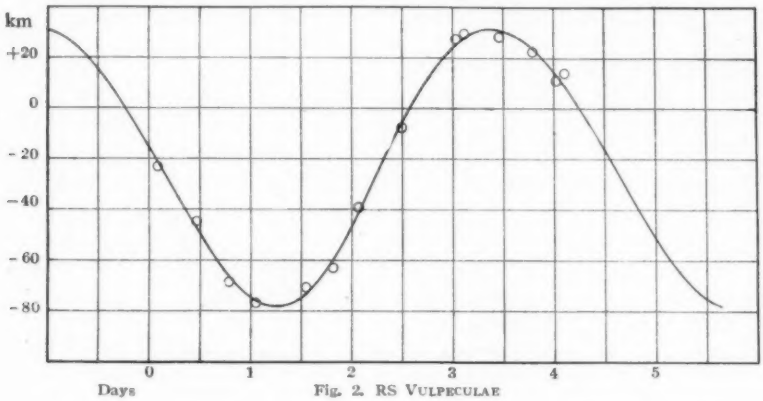


Fig. 2. RS Vulpeculae

sequently, there can be no doubt of the reality of the second spectrum even though the mass of the fainter body is only 0.31 that of the brighter, a greater difference in masses when both spectra appear than has previously been found. Why the second spectrum should be relatively so faint, when the two stars are of nearly equal brightness, is not apparent. It may be that, although the continuous parts of the spectra are of nearly equal intensity,the absorption lines of the second body are fainter than those of the primary, rendering them difficult to see when the continuous spectrum of the primary is superposed. Or again, a more likely explanation is that the lines are widened so much by the rotation of the large-diameter fainter star as to be made relatively very faint. One plate was

made about 2.2 hours after primary minimum, which, according to Stewart's orbit*, would be about an hour after the total phase so that, although it would receive most of the light from the fainter component, about one-fifth would come from the brighter. This spectrum has much the same character as the others, except that the lines are much weaker, and thus is in agreement with the above hypothesis. Further an additional plate was obtained on July 30 on Seed 23 emulsion and the finer grain enables the second spectrum to be more readily and certainly measured. On this plate the enhanced line 4549 is plainly doubled, the intensity of the second spectrum being relatively much stronger than in the other lines. Further the silicon pair 4128, 4131 show fairly strong companions, while the second spectrum in the hydrogen and helium lines is very weak. This would make it appear as if the faint diffuse companion were of Type B9 with relatively weak hydrogen and helium lines, while the bright dense star is B8 or even earlier. The relative intensities of the doubled lines 4549, 4131, 4128 in this spectrum are more nearly equal, being only about one-half as compared with one-fourth for the hydrogen and helium lines.

Altogether eleven lines have been measured in the primary spectrum, Hγ, Hδ; He 4472, 4388, 4144, 4121, 4026; Fe-Ti 4549; Mg 4481; C 4267; Ca, K 3934, and in the fine grained plate, Si 4128, 4131. The lines are of only fair quality for measurement, although much better defined than in *U Ophiuchi*, but the measures nevertheless are satisfactorily accordant, the probable error of measures of the primary spectrum on a plate being only ±1.8 km. per second.

In the table of observations given below, column 1 contains the plate number, columns 2, 3 date and Julian date of the observation and column 4 the phase from primary minimum computed from the original phase 2,419, 652.963 with a period of 4.477325 days from Stewart's photometric orbit†. Columns 5, 6 contain the velocities of the primary and secondary stars and columns 8, 9 the residuals, in the sense observed minus computed, from the final orbit. Column 7 contains the number of lines measured in the primary and where a second figure is present the number in the secondary spectrum.

*Astrophysical Journal, **42**, 315, 1915.

†*Astrophysical Journal*, **42**, p. 315, 1915.

TABLE II—OBSERVATIONS OF *RS VULPECULAE*.

Plate Number	Date 1919	Julian Date	Phase	Velocity		No. of Lines		Residuals O-C	
				Brighter	Fainter			Brighter	Fainter
1888	Apr. 26	2,075.981	0.786	− 68.3	+132.0	9	10	−2.30	+13.2
1912	" 29	078.988	3.793	+ 22.2		11		−1.28	
1987	May 6	085.969	1.818	− 63.2	+107.4	8	4	−3.20	+ 7.8
2243	July 1	141.903	4.024	+ 11.2		10		−2.11	
2269	" 3	143.903	1.547	− 70.7	+131.9	9	7	+2.98	−11.5
2298	" 7	147.883	1.050	− 76.9	+160.8	9	8	−0.99	+10.3
2316	" 8	148.902	2.069	− 39.1		7		+2.36	
2329	" 9	149.870	3.037	+ 27.5	−163.7	6	3	+1.96	−10.3
2350	" 13	153.818	2.507	− 7.5		10		−2.27	
2367	" 14	154.773	3.461	+ 28.2		7		−2.79	
2390	" 15	155.878	0.090	− 22.9		6		−1.91	
2428	" 18	158.897	3.109	+ 29.8		10		+2.07	
2441	" 19	159.892	4.104	+ 14.1		9		+5.08	
2449	" 20	160.727	0.462	− 44.4		6		+2.56	
2579	" 30	170.760	1.540	− 67.2	+132.2	9	8		−11.6

When these velocities and phases were plotted on cross section paper it was at once seen that the orbit was not circular. The photometric orbit does not show eccentricity, but this element can only rarely be accurately obtained from the light curve. Preliminary elements obtained graphically were assumed as follows:

e eccentricity	0.05
K half-amplitude velocity	54.0 km.
γ velocity of system	−22.65 km.
ω longitude of apse	240°
T time of periastron	1.903 days from minimum.

An ephemeris and observation equations calculated by means of Lehman-Filhés differential coefficients were computed for applying least squares corrections to e, K, γ and ω. Owing to the smallness of the eccentricity it was considered useless to apply corrections for both ω and T and the latter was considered fixed.

From this least square solution we obtain the following corrected elements:

$$e = 0.053 \pm .015$$
$$K_b = 54.98 \pm 0.79 \quad K_f = 175.9$$
$$\gamma = -22.04 \pm 0.56$$
$$\omega = 236°.26 \pm 0°.84$$
$$T = 1.903 \text{ days.}$$

The probable error of a single plate for the bright star is ±1.8 km. and for the faint ±8.1 km. per second. A graph of the orbit with the observations of the principal spectrum represented by circles is shown in Fig. 2.

Applying the above values we obtain by the well-known formulae

$a_1 \sin i = 3{,}388{,}000$ km.
$a_2 \sin i = 10{,}842{,}000$ km.
$(m_1+m_2) \sin^3 i = 5.70$. ⊙

Stewart's photometric orbit* gives two solutions, a uniform and a darkened. The uniform gives a value of the inclination 69° 45′, radius brighter star .090, radius fainter star .450, while the darkened solution gives 68° 25′, .0932, .460 for these three quantities. The dimensions, masses and densities in the orbit follow. For comparison the dimensions from Shapley's darkened orbit† are also given and it appears that further photometric work on this star is desirable.

	Stewart		*Shapley*
	Uniform	*Darkened*	*Darkened*
a semi axis relative orbit	15,190,000	15,300,000	14,230,000
a_b semi axis orbit brighter star	3,610,000	3,644,000	3,389,000
a in terms of sun's radius	21.84	22.00	20.47
a_b in terms of sun's radius	5.19	5.24	4.88
r_b radius brighter star	1.96	2.05	1.80
r_f radius fainter star	9.81	10.25	5.16
m_b mass brighter star	5.26	5.40	4.34
m_f mass fainter star	1.64	1.69	1.36
M total mass	6.90	7.09	5.70
ρ_b density brighter star	0.70	0.63	0.74
ρ_f density fainter star	0.0017	0.0016	0.008

If we assume the surface intensity of a B8 star to be -2.2‡ magnitudes and the sun's absolute magnitude to be 4.86 the absolute magnitude of the brighter component of *RS Vulpeculae*, with apparent magnitude 7.75, is $+1.09$ and the parallax is 0″.0046.

TW Draconis.

The eclipsing variable *TW Draconis* (α,15h 32.4m, δ,+64° 14′, 1900, Vis. Mag. 7.45; Spectral Type B9) was first observed on April 13, 1919, and the last plate obtained on July 17. During this interval fourteen plates were obtained, all of which are used in the orbit. They are not so well distributed as in *RS Vulpeculae* owing to the depth of primary minimum, when the star falls to

Astrophysical Journal, **42**, 315, 1915.
†Contributions from Princeton Observatory, No. 3, p. 90.
‡*Astrophysical Journal*, **40**, 415, 1914.

9.8 magnitude, making it impracticable to obtain plates at this epoch. The comparative faintness of the secondary, its light being 0.115 of the system, of course renders its spectrum unobservable.

The spectrum classed as B9 is in reality A3 judging by the relative strength of hydrogen and K and the number and intensity of the metallic lines, and in consequence should be capable of accurate measurement. Although the interagreement among the lines is fairly good, the velocities of the plates are disappointing, the residuals unexpectedly high, resulting in a plate error of ± 2.6 km per second. This is probably due to the rather wide and diffuse character of the metallic lines, making the settings uncertain. That the lines are wide should not be a cause for surprise when we consider the nearness of the two bodies and the probable rapid rotation of the bright body in the period of the system.

The data of the observations are given in Table III where column 1 contains the number of the plate, columns 2 and 3 the date and Julian date of the observation. Column 4 contains the phase from primary minimum computed from initial photometric phase 2,418,906.453 with period 2.80654 days, and column 5 the velocity determined from measures of the number of lines in column 6. Column 7 contains the residuals in the sense observed minus computed from the final orbit.

TABLE III—OBSERVATIONS OF *TW DRACONIS*.

Plate Number	Date 1919		Julian Date	Phase	Velocity	No. of Lines	Residuals O-C.
1802	April	13	2,422,062.890	1.886	+50.8	12	−2.33
1883	"	26	075.862	0.825	−63.2	20	−0.76
1909	"	29	078.922	1.078	−38.7	17	+3.99
1936	May	3	082.840	2.190	+62.2	12	−3.19
1982	"	6	085.865	2.408	+51.4	12	−4.47
2217	June	30	140.734	1.147	−37.3	17	−2.16
2233	July	1	141.721	2.134	+67.6	11	+2.40
2247	"	2	142.716	0.322	−47.9	7	−2.74
2275	"	6	146.733	1.532	+18.6	13	+4.53
2289	"	7	147.726	2.525	+50.3	11	+6.13
2306	"	8	148.726	0.719	−61.4	14	+4.37
2363	"	14	154.718	1.098	−48.1	15	−7.44
2383	"	15	155.722	2.102	+65.1	9	+0.45
2398	"	17	157.717	1.290	−16.4	11	+1.29

When these observations were plotted it was at once seen that by making the orbit slightly eccentric better agreement could be obtained than with a circular orbit. Although no eccentricity is given by Shapley's orbit,* it is probable that Nijland's observations are

*Contributions from Princeton Observatory, No. 3, p. 90.

not of sufficient accuracy to determine this and alternative solutions for eccentric and circular orbits gave considerably lower residuals for the former. Preliminary elements which were obtained graphically are as follows:—

Period from photometric orbit	2.80654 days
Eccentricity e	0.04
Semi-amplitude K	64.5 km.
Velocity of system γ	−0.5 km.
Longitude of Apse ω	90°
Time of Periastron T	0.020 days.

Owing to the smallness of the eccentricity it was considered useless to apply least square corrections to both T and ω and, in this case, as the latter seemed better determined by the graphical elements, a correction for T was used.

The result of the least square solution gives for corrected elements:

e eccentricity	.0536	±.0187
K semi-amplitude	65.78	=1.13
γ velocity system	−0.34	±0.91
T time of periastron	0.019	±.010
ω longitude of apse	90°	

$a_b \sin^3 i$ semi axis major = [6.40395] = 2,535,000 km.

$$\frac{m^3 \sin^3 i}{(m_b+m_f)^2} = [8.91696] = .0826 \odot$$

This function of the masses, all that can be determined when the second spectrum can not be seen, does not give us information in regard to the dimensions or masses of the system. From the photometric orbit we obtain the diameters of the individual stars in terms of the relative orbit, but the latter can not be known without the ratio of the masses. As a first approximation Shapley assumed the masses equal and later used an empirical formula* for determining the masses of the components. This formula, based on the relative light of the two bodies, has its constants determined from spectroscopic binaries in which both spectra show and the ratio of the masses are known. Using this formula $\mu_b = 0.4 + 1.2 L_b$ the ratio comes as brighter star 0.73, fainter star 0.27 total mass. If we use *RS Vulpeculæ* as an analogy where the system is somewhat similar, a dense bright small primary with a tenuous, large

*Contributions from the Princeton Observatory, No. 3, p. 123.

companion, it seems probable that the ratio of the masses assumed above is certainly not too great. With *RS Vulpeculæ* where the light of the brighter star is 0.526 of the system, the ratio of the masses is 3.20: 1, while with *TW Draconis*, where the light of the brighter star is 0.885 of the system, it would certainly seem likely the ratio of masses would be greater. Nevertheless, the ratio given by the formula has been used and I think may be safely considered as giving minimum dimensions to the orbit, but of course these dimensions depend upon this assumption and can not be considered absolute as in the two previous orbits. Using Shapley's two solutions, uniform and darkened, the inclinations are 75° 53′ and 79° 48′, while the semi-diameters of brighter and fainter are .130 and .371 for the uniform and .180 and .334 for the darkened.

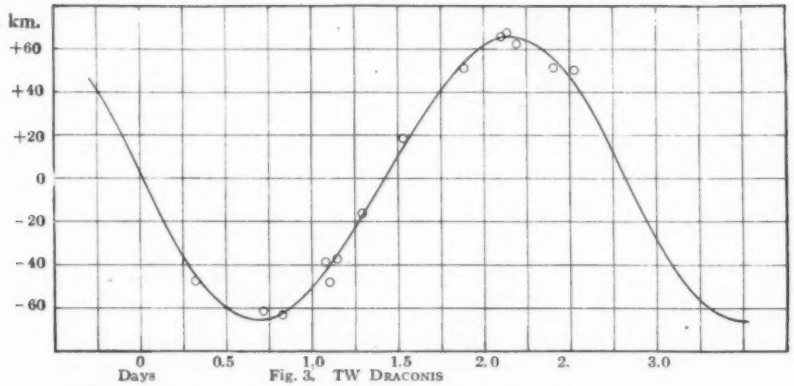


Fig. 3. TW Draconis

The dimensions of the system hence become

	Uniform	*Darkened*
a_b semi axis major primary orbit	2,614,000	2,575,000
a_f semi axis major secondary orbit	7,067,000	6,963,000
a semi axis major relative orbit	9,681,000	9,538,000
a in terms of sun	13.92	13.71
a_b in terms of sun	3.76	3.70
r_b semi diam. brighter	1.81	2.47
r_f semi diam. fainter	5.10	4.58
mass brighter star	3.36	3.21
mass fainter star	1.24	1.19
total mass system	4.60	4.40
density brighter star	.57	.21
density fainter star	.0094	.0124

A graph of the velocity curve with the observations as circles is shown in Fig. 3.

Conclusion

It may be of interest to summarize the dimensions of the two systems obtained here with the seven previously secured, that are known to me. The orbit of *TW Draconis* is not included in this summary as owing to absence of the second spectrum the dimensions are not absolute. The following table gives the principal dimensions using the darkened photometric orbit in each case, where there are two or more solutions.

TABLE IV—ABSOLUTE DIMENSIONS OF ECLIPSING VARIABLES.

Star	Greatest Radii		Masses		Densities		Distance of Centres
	r_b	r_f	m_b	m_f	ρ_b	ρ_f	
P Aurigae[1]	2.81	2.81	2.40	2.36	0.11	0.11	17.7
u Herculis[1]	4.56	5.35	7.66	2.93	0.095	0.022	14.8
V Puppis[1]	8.45	7.70	19.4	19.4	0.042	0.055	12.7
B Lyræ[1]	16.2	40.6	1.42	14.2	0.0006	0.0004	59.9
RX Herculis[2]	1.54	1.38	0.89	0.89	0.25	0.34	7.5
W Ursæ Majoris[3]	0.78	0.78	0.69	0.49	2.8	1.9	2.2
Z Herculis[4]	1.77	3.29	1.6	1.3	0.3	0.04	15.1
U Ophiuchi	3.23	3.23	5.36	4.71	0.18	0.16	12.8
RS Vulpeculae	2.05	10.25	5.40	1.69	0.63	0.0016	22.0

The above table is self-explanatory if it is stated that the linear dimensions are in terms of the sun's radius and the masses and densities in terms of the mass and density of the sun. Fig. 4 gives a graphical representation of the dimensions of the systems of *U Ophiuchi* and *RS Vulpeculæ* and of the assumed dimensions of *TW Draconis* in terms of the sun. The intersections of the vertical and horizontal dotted lines represent the centres of mass of the systems. The series of figures to the left are the systems at primary eclipse and those to the right, a quarter revolution away, when at maximum separation. No attempt has been made to represent the stars as elliptical in form in this figure.

There is one other point in connection with these orbits, the coincidence or otherwise of the photometric and spectroscopic phases. Dr. Schlesinger has found in Algol, δ Librae and *u* Her-

[1] *Astrophysical Journal*, **38**, p. 169.
[2] *Astrophysical Journal*, **40**, p. 399.
[3] *Astrophysical Journal*, **49**, p. 189.
[4] *Astrophysical Journal*, **49**, p. 192.

culis that the phase of mean primary eclipse comes slightly later, about an hour or so, than the time when $u=90°$ in the spectroscopic orbit, while it is evident the two should coincide. No explanation is offered for this discrepancy and it will be of interest to compare the results for the three variables discussed here.

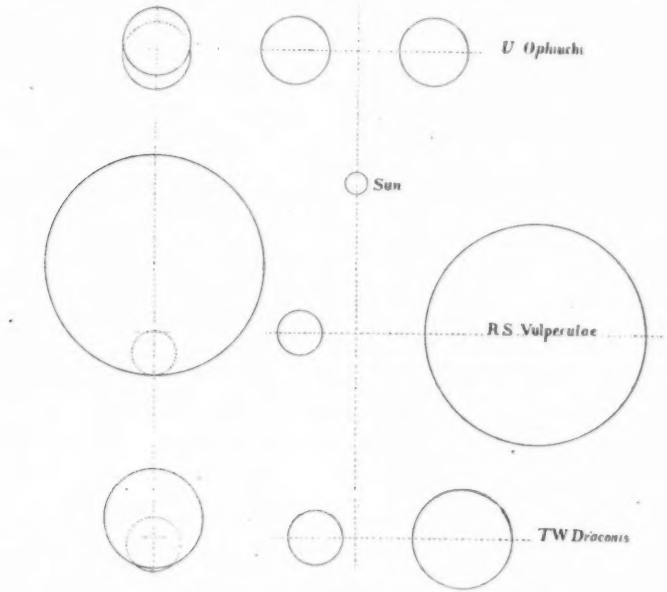


Fig. 4. Graphical Representation of the Systems

In *U Ophiuchi* no attempt was made to apply a correction for θ, the phase in the circular orbit, owing to the high probable error and to the fact that nearly all the observations were near their maximum velocity, where they would have little weight in the determination of this correction.

In *RS Vulpeculæ* the velocity curve shows that the spectroscopic phase is considerably later than the photometric and if the time when $u=90°$ is computed it is found to be $+0.128\pm0.010$ days. In *TW Draconis* $\omega=90°$, therefore the time when $u=90°$ is the time T found in the orbit, or $+0.019\pm0.010$ days. In both

these cases therefore the spectroscopic phase is later than the photometric by about 3 hours in *RS Vulpeculæ* and 27 minutes in *TW Draconis*, in the opposite direction to that found by Schlesinger.

It is hard to imagine any physical cause which would account for a difference in phase in one direction in some instances and in the opposite direction in others and though the differences appear to be considerably too great to be explained by errors of observation in either the spectroscopic or the photometric orbits, there seems to be no other alternative until more data is available.

DOMINION ASTROPHYSICAL OBSERVATORY,
VICTORIA, B.C.
AUGUST 6, 1919.

PIN-HOLE OR LENSLESS PHOTOGRAPHY

By H. W. Barker

It is not my intention to enter into the science of lensless photography, but merely to explain in a few words the construction of the camera and point out some of the advantages and disadvantages of this simple and interesting method.

It is, of course, well known that a lens is not essential to picture-taking. All that is required is a small hole through which the rays of light can pass and throw the image on the sensitized plate. I read somewhere that the idea of making such a camera occurred to a man, who, when lying in bed rather late one morning, noticed before him on the wall the image of a cow grazing. Upon investigation he found that there was a pin-hole in the opaque green blind which was drawn down, and through this little aperture there was projected the picture of the cow on the common outside. I am not prepared to vouch for the truth of this story, but it remains that the pin-hole camera is nature's method of taking pictures.

Several years ago I picked up a copy of the "Photo Miniature" —a publication which each month is devoted to some particular branch of photography. This number was on pin-hole photography. It was written, if I remember aright, by a Scotch clergyman named Thompson. By charts, drawings, and written description the writer gave very minute instructions about the making of the box and the needle-holes, and by following these instructions the very crude contrivance which I use came into being.

In this camera there are four separate needle holes, the centre being the one generally brought into play. The upper hole is used when it is desired to raise the picture on the plate. This has the same effect as elevating the lens on an ordinary camera. The two side holes are for taking stereoscopic pictures, a partition being inserted to divide the inside of the box into two sections. There are slots cut in the side for holding the plates, which may be placed in almost any position in the camera. More will be said about

this in a moment. The making of the needle holes is the most important thing of all. This is rather a delicate operation and requires great care, for if they are not properly made good pictures cannot be taken. On the bottom of the box is a brass plate to which to attach the tripod.

The following are some of the advantages of this class of photography:

(1) Any handy man or youth can make a camera for himself at the outlay of a few cents. The present high cost of living does not necessarily enter into the realm of photography.

(2) In plate photography with the ordinary camera one of the most annoying things is the trouble involved in focussing on the ground glass with a black cloth over the head. With the pin-hole this annoyance is done away with, for we have universal focus. No matter how near or how far away the object to be photographed, and no matter in what part of the camera the plate may be, it is always in focus. The pictures are never clear-cut, it is true, but are what photographers call a little "fuzzy", and therefore perhaps more natural.

(3) You are aware that some lenses cover a wide angle, while others are more limited in their range. Here we have both wide and narrow. In order to take in the wide range, instead of changing the lens or adjusting the pin-hole, all that is required is to put the plate nearer the front of the box. Draw imaginary lines from the edge of the plate, wherever it may be, to the pin-hole, and every object within these lines extended will be included in the picture. It follows also that the nearer the plate is to the pin-hole the shorter will be the exposure, but no exposure for an ordinary picture is less than one minute. I have taken a photograph with the camera pointing directly at the sun. In this case the exposure was three seconds. The longest exposure I have made was in a church, the shutter being open for eight hours—nearly ten thousand times as long as for the sun picture.

(4) As long exposures are necessary, moving objects are eliminated. It is impossible, as we all know, to take a picture along one of our busy streets with an ordinary camera and not show the traffic, but a photograph taken with this box shows a clear street every time.

(5) The pin-hole method gives an absolutely correct perspective. There is not the slightest distortion of lines. In ordinary photography, even the rectilinear lens does not make a perfect picture.

I have stated some of the advantages of lensless photography. Of course there are a few slight disadvantages also. One is, that the camera is necessarily bulky and therefore difficult to carry about. Another disadvantage, as we have already seen, is that snapshots cannot be taken. Again, only one plate can be carried at a time, but this can be overcome by arranging a light-proof receptacle into which the plate-holders can slide.

A GLOBE OF THE PLANET MARS

The small globe of the Planet Mars which I was privileged to show at a recent meeting of the Society was the outcome of an idea that came to me on reading a letter addressed to M. Camille Flammarion by an invalid French lady who had beguiled the weary hours spent in her sick-room by constructing a globe of Mars. I felt that if a lady could, under such unfavourable conditions, make a globe, I, with the aid of several good charts in my possession supplemented by my own observatory notes and drawings, might try to follow her example. While I do not claim any artistic excellence for my work I can say that the various features depicted are all properly located. Transferring these from the charts to the curved surface of the globe led me to appreciate as I had never done before the vast amount of observational study and accurate measurement the construction of the charts must have involved. Further, the work has impressed the Martian features on my memory more effectually than all my previous study of maps and drawings. And lastly I have been pleased as well as surprised to realize how many of these markings, often faint and delicate, were familiar to me from my own study of the planet with a telescope of only 4 inches' aperture. Readers of the JOURNAL may recollect that in a paper printed about eighteen months ago I called attention to the utility of small telescopes for Martian observation.

A. F. M.

THE FESTIVAL OF THE DEAD

By R. G. Haliburton

EXPLANATORY NOTE

Robert Grant Haliburton was the son of Thomas Chandler Haliburton, a Nova Scotia judge and later a British M.P., but better known as the creator of "Sam Slick". He was born at Windsor, N.S., on June 3, 1831, and was educated there, graduating from King's College at the head of his class. He took his M.A. degree in 1852 and was given by his alma mater in 1876 the honorary degree of D.C.L., in recognition of his scientific researches.

In 1853 he was called to the bar and became a leading lawyer in Halifax. He spent five years (1871-76) in England, writing and speaking on political matters chiefly relating to the consolidation of the Empire. Returning to Canada, he settled in Ottawa in 1877 and acquired a large practice there. In 1881, on account of ill-health, he gave up his law practice and spent the winters in warmer climates. While in Jamaica he recognized certain poor conditions there and by drawing the attention of the English public to them an act of parliament was passed removing the trouble.

Haliburton published many political, scientific and literary papers. One of the first was "The Festival of the Dead", which was presented to the Nova Scotia Institute of Natural Science (of which Haliburton was the founder) and which, with additions, was afterwards printed privately in 1863. Several of his papers related to dwarf races in North Africa, and in 1890 and 1891 he spent nearly eight months in Morocco making inquiries into this subject. He also published poems, "Voices from the Street" (N.D.) and "Homespun Songs by Samuel Slick, Jr." (1873).

The paper on "The Festival of the Dead" contains much information regarding the connection of the calendar of primitive peoples with the Pleiades, and in this field Haliburton is recognized as a pioneer. The paper received favourable comment in various works and down to the present time references have continued to be made. But the paper itself is extremely scarce and as it was written by a distinguished Canadian on a subject still of great interest it was felt that it was worthy of republication. It has been put in type from photographs of the copy in the Library of Congress, Washington, D.C. At the end of the original publication was a short paper entitled, "The Unity of Origin of the Human Race, Proved by the Universality of Certain Superstitions Connected with Sneezing," but it is omitted here.

Haliburton died on March 7, 1901.

PREFACE.

Note.—The pages referred to in the text are those in brackets at the bottom of the page.

Some very important facts relating to our history of the Deluge, were forced upon my attention by Greswell's speculations, after the paper on the Festival of the Dead, the Addenda, and the Introduction were printed, a circumstance which will prove how averse I have been to touch upon this subject, or to search for peculiarities in our narrative of that event, for confirmations of my conjectures.

This supplementary evidence, mentioned in p. 118, relieves me from a very serious responsibility, and enables me to ask the reader to dismiss my conclusions, if not my data on this point, entirely from his consideration. Let him first, however, remember that the Aztecs, and the ancient Egyptians, like the Australian savages, held their great festival "when the Pleiades were most distinct," that the two former races regarded their celebration as a commemoration of the Deluge, and that the Egyptians and the Hebrews attached the memory of that event to the same month, and probably to the very same day; then let him read Sir William Jones' works as to the astronomical character of the Hindoo traditions on the subject, which are based on the two periods of 72, and of 25920 years, to which their cosmogony and history of the Deluge are supposed to have reference. Let him remember that Thor's 540 halls, multiplied by 48, make 25920; that Noah is pronounced by Sir Wm. Jones to be one and the same personage with the Hindoo Menu, and that the periods of Menu consist of 72 years. Let him then turn his attention to Greswell's speculations as to the 72 descendants of Noah, and the 72 priests of Apis, and let him apply to our history of the Deluge the same simple test by which Sir William Jones demonstrates the astronomical character of the traditions of the Hindoos. Why that eminent writer did not carry his speculations one step farther, and try whether the similarity which he discovered, did not also extend to these astronomical peculiarities, it is difficult to explain, as all that he had to do was to divide 1656, the era between the creation and deluge, by 72, and the result would have been as conclusive as his previous deductions. It can hardly be assumed that he shrank from the enquiry, or suppressed the inference to which he had been led, a step to which no candid enquirer would resort.

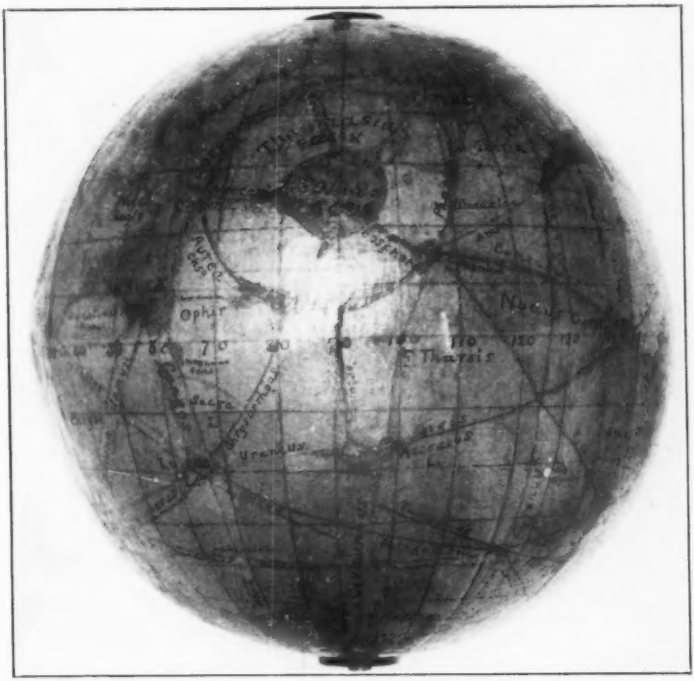
Having had my attention drawn to this point by the investigations of others, I should consider it unfair to truth to abstain

PLATE I

VIEW IN THE DON VALLEY, NEAR TORONTO
Pin-hole photograph by H. W. Barker
Exposure 1 minute

INTERIOR VIEW IN BROADVIEW Y.M.C.A. BUILDING, TORONTO
Pin-hole photograph by H. W. Barker
Exposure 1 h. 15 m.

PLATE II



GLOBE OF MARS
Drawn by A. F. Miller
(See page 18)

from alluding to it. We need not ask whether any sincere Christian, but whether any honest man, would for a moment justify us in shunning an enquiry that has not been willingly entered into, and that could not with propriety have been avoided. Shall the Hindoo say to us, "you have come from the uttermost parts of the earth to try our traditions by a test, which you dare not apply to your own"?

Until the facts mentioned in p. 23 attracted my attention, I had never entertained any doubts as to our narrative being in all its details of an historical character. The points that have arisen, and which have hitherto escaped observation, must necessarily have forced themselves upon my notice, if no question had ever been raised on the subject, and if the incidents of that event had come down to us divested of all those difficulties that have suggested themselves to geologists and to matter-of-fact logicians.

These investigations into the calendars and festivals of nations were commenced partly as an amusement, and partly as being likely to lead to important results as respects ethnology. During the past nine years the subject of the Deluge did not appear to be connected with these researches, or was avoided as not being an inviting or necessary branch of enquiry.

As I am not qualified by my tastes or by my studies for theological controversies, I must leave this important question to Divines, and to those more worthy or more competent to discuss it than myself; and I am only too happy to refer them to Sir William Jones, Bryant and Greswell, as far more reliable authorities on the subject than myself. My inferences were arrived at by a tedious comparison of calendars, festivals, symbols and traditions; while those eminent authors lead us to conclusions, some of which being based on chronology, are the more important, as they can be reduced to a simple matter of arithmetical calculation.

The only portion of the paper on the Festival of the Dead to which I would invite attention respecting this subject is that (p. 103) in which it is attempted to be shown that these investigations suggest a new explanation for the difficulties in our narrative, and lead us to infer that it embodied primitive traditions in language in accordance with the remarkable peculiarities of the age in which it was written; and that it was intended and understood to be partly a memorial of the Flood, and partly a record of a great philosophical truth that was a heritage from primeval man. This truth, it is clear, must have been a gift from the Deity to our first parents, a gift by which the beneficent design of the Creator, that "the lights in the firmament of the heaven" should be for "*signs* and for *seasons* and for days and *years*," was accomplished,

from the very hour when creation gave birth to time and to humanity. The divine origin of this heritage must have been long treasured up in the memory of men.[1] The sacred *Tau* of the Egyptians, always placed in the hands of their divinities, was regarded as "one of the greatest gifts bestowed by the Deity on man." This symbol, I have endeavored to show,[2] was the emblem of the primeval calendar, which still exists in the Southern Hemisphere, as the year of the *Tau* or of the Matarii (the Pleiades). But unlike the Hebrews, the heathen nations of old appear to have turned the blessing into a curse, and to have confounded the gift with the giver; and thus Time or the Year converted into a God, and concealed from the eyes of men in a veil of mystery, became the fruitful parent of many Deities.[3]

[1] See extracts from Greswell, p. 41; also note to p. 91.

[2] See note, p. 96

[3] It will not be amiss to mention here a fact that has hitherto escaped my notice, which confirms the view that the Festival of the Dead was regulated by the Pleiades. It would appear that the ancients combined with their worship of Time or the Year, their superstitious veneration for deceased ancestors. Hence the commemoration of the dead became a new year's festival, and the Pleiades were regarded as the Stars of Death or of the god of the dead. It has been conjectured by me, that the *Seven Cabiri*, whose mysteries were so venerated by ancient nations, were the seven Pleiades, and that their name, like that of the *Cabaries* of Madagascar, and of the Australian corroborees, was derived from the Samang word *kabis* (death).

Crawford, in his work on the Indian Archipelago (II. p. 142), gives a vocabulary of 18 dialects, which, he says, belong in common with those found throughout the Pacific Islands, to the great Polynesian language. On examining it we find that the word for death, which in one instance is *kabis*, in 10 out of the 18 dialects selected, occurs as *mati, mate, matai*, or *mortê*. We can hardly doubt that *Matarii* is synonymous with *Cabiri*, and that both mean the *Stars of Death*. The significance of the Polynesian name for the Pleiades, *Matarii*, will be more apparent if we substitute for matai the word mortê, and call them the *Mortêrii*. See note on p. 28; also pp. 61, 44, 72, 93, 111, 121.

It may also be well to explain a point to which I have not hitherto referred, respecting our history of the Deluge. I have assumed that the year indicated by it consisted of months of 30 days each, as the interval between the 17th day of the 2nd month, and the 17th day of the 7th is apparently described as 150 days. If the term "yet other seven days" in v. 10 has the meaning which some commentators assign to it, it supplies an additional proof of the astronomical nature of the narrative; as we find that the first occasion, when the dove was sent forth, was on the 17th day of the 11th month; the second (when it returned with the olive leaf or branch) was on the 21st of August, when the Pleiades culminate at sunrise; and the third, when it finally left the ark, was on the 28th of August, which was the last day of the Egyptian year, and among the ancient Romans was a conspicuous anniversary, as it still is among the Chinese and Japanese. The chronological evidence, however, to which I have referred, is much more satisfactory than the inferences derived from calendars, which must be more or less the subject of conjecture, or at least of doubt and discussion. The subject touched upon here is alluded to in on p. 60 and foll.

Common sense, as well as common justice, demands that critics should test our history of the Deluge, as they would examine any literary production of remote antiquity, by the light of the age in which it was written. If we remember the singular tendency to make use of astronomical parables or allegories, that then existed, a tendency that must have been palpable and familiar to all men, though it too soon became among heathen nations the perverted source of pagan mythology,[4] we can see that equal injustice is done to that portion of the Holy Scriptures by those who insist on its being of a strictly historical nature, and by those who, unable to adopt that view, doubt its inspired character, and regard it as an unmeaning fable.

To discuss such a question in a spirit of bitterness or recrimination, would be to degrade it into a battle field for rival critics. I feel persuaded that all the difficulties we imagine to exist will be removed by a candid consideration of the subject; that to invite a verdict on the question whether our account of the Deluge is an historical narrative or an empty fiction, would be to stake the truth on a false issue, and would be asking the reason or the faith of the Nineteenth Century to sit in judgment on the production of an age, the spirit of which must have been altogether foreign and opposed to the genius and modes of thought of the present day.

It is plain that the discussion of this subject must sooner or later be inevitable. We may silence, but we cannot stifle enquiry; nor can we transfer to the next generation the responsibility which has devolved upon ourselves.

How any person of ordinary intelligence can either question the inspired character of the Holy Scriptures, or deprecate fair and honest investigation into truth, seems incomprehensible. Those who object to science as dangerous to revelation, might as reasonably close our observatories, lest enquiries into the spots on the sun might lead men to doubt its luminous nature, or might diminish the rays by which it diffuses the light of day throughout the world.

[4] I would invite attention to the passage on this point cited by me in p. 86, by which it would appear that astronomical myths of the same type almost simultaneously appeared in India, Egypt, Greece, and other countries towards the close of the 14th century B.C., i.e., about 350 years after the time of Moses.

INTRODUCTION.

The following paper contains the results of investigations commenced in 1853. Accident drew my attention to the antiquity of popular customs, a point long known to the learned, and to the public through Brand's Popular Antiquities and other works. Finding that some of the superstitions and observances of the peasantry of the Mother Country are to be found among the Indian tribes of America, I felt convinced that if the fact could be established, it would open up a new mine of materials for the history of man, and would probably establish the unity of origin of our race. It was, however, apparent that in order to ascertain what are *universal* customs and festivals, it was necessary to devote several years to the somewhat wearisome task of collecting data, out of which to select materials for these investigations. Accordingly, I devoted my leisure to this very laborious undertaking, in the course of which I found the number of universal customs far greater, and the identity between them much more striking that I had anticipated. Having had rather unexpectedly to visit England in 1859, I thought it advisable to prepare a brief paper for the Society of Antiquaries of London, and accordingly selected customs connected with All Souls Day as a subject. On outlining it in England, it was apparent that the coincidences in the observance of the festival by different nations were much more striking than I had supposed. But a new and most startling fact was discovered when I came to read over the paper I had prepared. Rivero had remarked that it was singular that the festival of the dead amongst the ancient Peruvians was celebrated on the same day as by the Spaniards, viz., on All Souls Day, November 2nd. I had also considered this merely as a curious coincidence; but it was apparent on reading over the results of my investigations, that the festival was *generally observed in November* south as well as north of the equator, a fact so remarkable that it was evident that whatever could be the cause, it must be something hitherto unknown to astronomers and to historians. I therefore did not regret that my having to return to America before the time when I was to have read the paper at a meeting of the Society of Antiquaries, gave me an opportunity of investigating this very remarkable question, before bringing the subject to the notice of the public. From 1859 until the present year, all the leisure that could be spared from public and private engagements, has

been devoted to the enquiry. It was evident that the uniformity could not have been caused or preserved by any calendar now known to us, and that the festival must originally have been regulated by some visible sign or mark that nature had supplied to our ancestors and to the Peruvians.

Suspecting that the rising of some constellation must have been the guide by which in remote ages this festival was regulated, I turned my attention to the Pleiades, as Humbolt alludes to the remarkable traditions that existed respecting them throughout ancient Europe and Asia. I found November, in India, called the month of the Pleiades; but it was perfectly clear that that constellation rises, not in November, but at the beginning of summer. The following paper will show how the problem was worked out by the aid of the Australian festival of the Pleiades in November.

But after the fact that in ancient times the festival of the dead must have been regulated by the Pleiades, had been demonstrated, a further difficulty arose; the Pleiades rose nearly a month earlier 2,000 years ago than they now do; hence the festival must have once fallen in October, or the months must have in some way moved onward in the same ratio with the progression of the year of the Pleiades. The results of my investigations on this point, if correct, will be new, and not a little interesting to astronomers.

A remarkable fact, however, was incidentally forced upon my attention: that the memory of the deluge was by the Mexicans, the Egyptians and the Jews associated with the same time of the year, and by the two latter nations as well as in Greece, was attached to the 17th day of the month; and with that day I had found some very peculiar superstitions connected, in the Pacific Islands as well as among most ancient nations. Among the Aztecs as well as the Egyptians, the deluge was commemorated at the beginning of the year of the Pleiades, *i.e.,* when that constellation culminated at midnight.

A subsequent examination of the traditions as to Taurus having once opened the year, proved that that constellation among almost all nations was connected with the deluge. Further investigation as to the origin of the use of eggs as a symbol of the beginning of the year made it evident that a bird was associated with the beginning of time, and with creation, and that the *Deluge* and *Time* were considered as *synonymous* by the ancients.

The fruits of these enquiries into these curious facts have been very unexpected by me, and will, I believe, be most interesting to theologians as well as to scholars. If the results of these investigations, contained in the following paper and the addenda, are correct, the year of the Pleiades and in its new year's festival

of agriculture and of the dead, will shed an entirely new light on the origin of pagan idolatry, and on the history of the deluge, and will supply some very conclusive arguments in favor of the unity of origin of mankind.

These are, of course, very important points, any one of which is sufficient to interest not only the learned, but also general readers. I have been exceedingly surprised at the results of these investigations, which have been much more interesting than I ever supposed they would prove, and are likely to throw some light on questions, which, when I commenced writing the following paper, I had not the most remote idea would prove to be connected with the field of enquiry which I was exploring. It is satisfactory for me to find that my conclusions are borne out indirectly by all previous writers on these subjects, who must have arrived at the same conclusions as myself if they had had their attention drawn to the connection of the Pleiades with the calendars, the commemorations and the mythology of antiquity.

It is hardly necessary to apologize for the form in which I submit the results of my labors. The paper on the Festival of the Dead was prepared for the transactions of the Nova Scotian Institute of Natural Science, and was substituted for one, which being rather intended as an amusing sketch of the universality of some trivial superstitions was regarded by me as hardly adapted for publication by a scientific society. The favorable reception which it has met with from some eminent authorities in the scientific world, I can only attribute to the whole scope of the paper being devoted to establishing the literal interpretation of our history of the Creation, and to disproving the theory of there having been different "centres of creation," at least as regards the human race, by showing the universality of certain trivial superstitions that must have been inherited by all nations from a common source. Whatever conclusions I may have since been forced to arrive at on other points, the spirit in which these investigations were commenced, will be apparent from the concluding paragraph. The present paper substituted for it was written in the course of a few weeks, and in the midst of public and private engagements, and the space at my disposal proved far too limited to do justice to the subject. Since its publication in June last, I have gone on making further investigations, the results of which were successively printed in forms of eight pages each, as addenda, so that the progressive character of these investigations will be apparent and their correctness or their fallacies demonstrated by the very defects of the paper itself. The addenda were at first only intended to occupy a few pages and were privately printed for circulation among those who might be interested in such mat-

ters, which will explain and perhaps afford an excuse for the references to my own opinions and to the different steps taken by me in prosecuting these enquiries.

The new facts, however, that were constantly opened up, induced me to continue these researches, until the paper and the addenda have assumed their present dimensions. Nearly every page will be found marred by misprints, and probably not a few mistakes may be found; though none, I believe, affecting the correctness of the conclusions to which I have been led, will be discovered. But my conjectures as to the origin of the festival and its connection with the year of the Pleiades will, I feel convinced, be fully borne out by further enquiries; and the new facts collected by me as to the history of the Deluge can scarcely fail to be regarded as important, even if my conclusions are not accepted as correct. It may seem to be an act of presumption for any person to venture to submit to the attention of scholars a solution for some of the most difficult questions connected with the history of our race, questions that have engrossed the attention of most learned authors, and most eminent astronomers. But the charge of presumption may appear more peculiarly to apply to a Colonist attempting to supply a clue that has hitherto been sought in vain, especially when his paper appears in the transactions of a Colonial Scientific Society. As the charge would be, I feel, entirely uncalled for, I have thought it advisable to explain the mode of enquiry which I have adopted, and for which the only qualifications required were the possession of very ordinary ability and a patient endurance of several years of literary drudgery.

More than half a century ago Sir William Jones was led to the very threshold of this subject, and seems to have foreseen that a comparison of the dates of festivals in different countries would supply new materials for the History of Man. Had he examined the field, which under peculiar difficulties I have been led to explore, and had he extended his enquiries to the festivals and calendars not only of the Hindoos, but also of more primitive races, the prestige of his great name would long ago have sanctioned the conclusions to which these investigations inevitably lead.

Under these circumstances, I shall use the words with which he introduces the subject of his researches, as a preface to my own:—

"The great antiquity of the Hindus is believed so firmly by themselves, and has been the subject of so much conversation among Europeans, that a short view of their Chronological System, which has not yet been exhibited from certain authorities, may be acceptable to those who seek truth without partiality to received opinions, and without regarding any consequences that

may result from their inquiries; the consequences indeed, of truth cannot but be desirable, and no reasonable man will apprehend any danger to society from a general diffusion of its light; but we must not suffer ourselves to be dazzled by a false glare, nor mistake enigmas and allegories for historical verity. Attached to no system, and as much disposed to reject the Mosaick history, if it be proved erroneous, as to believe it, if it be confirmed by sound reasoning from indubitable evidence, I propose to lay before you a concise account of Indian chronology, extracted from Sanscrit books, or collected from conversations with Panditis, and to subjoin a few remarks on their system, without attempting to decide a question, which I shall venture to start, *"whether it is not in fact the same with our own, but embellished and obscured by the fancy of their poets and the riddles of their astronomers."*—Sir William Jones *on the Chronology of the Hindus.*

MEETINGS OF THE SOCIETY

AT TORONTO.

December 16, 1919—The Society met at 8 p.m. in the Physics Building of the University of Toronto, the President, Mr. A. F. Miller, in the chair.

Prof. Chant gave an account of the steps that had been taken during the past six months to secure a site for an Observatory in Toronto, which would be also a home for the Society, and he read a letter he had just received from the City Clerk, Mr. W. A. Littlejohn, stating the exact terms upon which the Board of Control and the City Council had made the grant of land for the building.

Mr. Miller referred to the importance of the grant secured for the Observatory, and to the perseverance Prof. Chant had shown in carrying forward a project that had been initiated some years ago, but had been held back for five years on account of the Great War.

The Recorder gave a report of the results of the Council Meeting on December 3:

That Prof. Chant and Mr. Miller had reported on the proceedings at the conferences of the Observatory Committee with the Board of Control of Toronto. That Mr. Miller had reported on the negotiations carried on with the Royal Canadian Institute regarding the rent of the Society's room, and the Council had taken steps to deal with the matter and to provide accommodation also for mounting, at an early date, the 7-inch telescope belonging to the Society.—That Mr. Miller had also given a report upon bonds held by the Society and his course with regard to them, and his action was confirmed by Council.—That the Curator had been requested to obtain from those having borrowed instruments from the Society reports upon the present status of the instruments.

That the following nominations for officers for 1920 had been made, viz.: *Honorary President*—Otto Klotz, LL.D., D.Sc., etc.; *President*—Mr. J. R. Collins; *First Vice-President*—W. E. W. Jackson, M.A.; *Second Vice-President*—Wm. Bruce, J.P.; *Secretary*—A. F. Hunter, M.A.; *Treasurer*—Mr. H. W. Barker; *Recorder*—Mr. Joseph A. Pearce; *Librarian*—Prof. C. A. Chant; *Curator*—Mr. Robert S. Duncan.

Council—Sir Joseph Pope, Ottawa; Rev. D. B. Marsh, Pickering; John Satterly, M.A.; Dr. W. M. Wunder; Samuel Beatty, M.A., Ph.D., and Mr. Stuart Strathy. And finally that a special committee of the Council had been appointed to consider any desirable changes in the Society's Constitution.

The following were elected members of the Society: Miss E. G. Banks, Toronto; Thos. Stalker, Toronto; V. V. Ramanan, M.A., Ph.D., etc., Madras, S. India; Peter L. Trout, Toronto.

Mr. Miller reported that he has continued to observe Nova Aquilae 3, which is now between the 8th and 9th magnitude, and gives a bright line spectrum similar to that shown by it on former occasions.

Prof. Alfred Baker gave the address of the evening on "Astrology", which aimed at foretelling the future from the heavenly bodies. It undertook, in its day, to throw light upon the relations the Deity was supposed to have established between the constellations and the planets, and human affairs by the use of the horoscope. The lecturer cited references to astrology in the Bible, and in the literature of Chaldea, Greece and Rome. In the Middle Ages Astrology flourished all over Europe, everyone either casting a horoscope or having one cast for him. Prof. Baker exhibited examples of horoscopes, and explained their interpretation by the use of tables on the blackboard. At the present time Astrology flourishes in India, and there are instances of the survival of palmistry in this country. There is a journal devoted to the subject published in Boston. Owing to its use of the geocentric theory, it probably delayed the progress of astronomy in the earlier centuries. Forecasting the future was a practice almost universal, extending to the animal, vegetable and mineral kingdoms without restriction. The lecturer explained how they cast a horoscope,—indicating the functions of the various houses, planets, and constellations, both the sun and the moon being considered as planets for astrological purposes.

The chairman stated that Mr. Thomas Lindsay, a former member of the Society, had devoted much attention to the subject of astrology, not because of any belief in it, but for a better acquaintance with the ideas of former times.

Several other members contributed some interesting remarks to the discussion, and after a cordial vote of thanks to the lecturer for his interesting address, the meeting was adjourned.

A. F. HUNTER, *Recorder.*

AT OTTAWA.

The Annual Meeting of the Ottawa Centre of the Royal Astronomical Society of Canada was held in the Carnegie Library, Ottawa, on Friday, December 19th, 1919, at 8.00 o'clock, the President, Mr. Charles A. Bigger, presiding.

The minutes of the last annual meeting were read and adopted.

Mr. J. L. O'Connor was elected to membership in the Society.

The following names were proposed for membership in the Society: J. W. Pierce, W. M. Christie, W. P. Daly, Colin S. Macdonald, P. E. Palmer, R. C. Purser, Joseph Hardouin, C. P. Hotchkiss, W. J. Boulton, G. C. Cooper, Lucien Brenot, M. D. McCloskey, A. O. Gorman, P. A. Shaver, Edwin F. Gorman, K. F. McCusker, F. W. Beatty, T. H. Plunkett.

The reports of the Treasurer and Secretary were presented and adopted. The books showed a small balance on hand. The membership showed an increase over that of the previous year, eight new members being elected besides eighteen proposals to be dealt with at the first regular meeting of 1920.

The following officers were elected for 1920: *President*, Mr. Charles A. Bigger; *Vice-President*, Dr. W. Bell Dawson; *Treasurer*, Mr. D. B. Nugent; *Secretary*, Mr. R. M. Motherwell; *Councillors*, Mr. Thos. Fawcett, Dr. R. E. Delury, Mr. Albert Hawkins.

After a short discussion regarding the future policy of the Society the meeting adjourned.

R. M. MOTHERWELL,
Secretary, Ottawa Centre.

AT VICTORIA

The annual meeting was held on December 16, 1919, in the Girls' Central School. The officers elected were: *Hon. President*, Dr. J. S. Plaskett; *President*, Dr. R. K. Young; *Vice-President*, Mr. J. Umbach; *Secretary*, Mr. K. M. Chadwick; *Treasurer*, Mr. J. P. Hibben; *Auditor*, Mr. T. Shotbolt; *Executive Committee*, Mrs. Christopher, Dr. Etta Denovan, Mr. F. C. Green, Mr. W. E. Harper, Capt. G. G. Aitken and Mr. G. S. McTavish.

After the business of the evening was concluded, Dr. Plaskett gave an address showing the gradual change and development in ideas about astronomy and the state of the universe. He stated that the most marked advance had been made during the last twenty years. "Herschel had brought forward good ideas of the formation of the universe. He said that the shape of the universe was like a grind-stone. He gave us some idea of the shape of the stars, but nothing regarding dimensions. This has been accepted for 100 years. During the last ten or fifteen years, however, we have been able to measure the distance of stars and since that there has been some change in our ideas. We believe the world is something about the same shape as propounded by Herschel, but at Mt. Wilson the measurement of globular clusters enlarged the preconceived idea of the dimensions of our universe, with the result that we have been forced to enlarge the dimensions of the whole system.

"We now know that the universe is not nearly so simple as we once thought it to be. We know that the sun is not in the centre of it, but to one side."

The new theory of "relativity" as propounded by Einstein was also touched upon by Dr. Plaskett. "It alters the theory of gravitation, changes our ideas of space and time, and in fact all our ideas of science have to be modified", said Dr. Plaskett. "Einstein made three predictions based upon his theory, two of them have been proved by observation and measurement, but the third failed.

"Some of the results of this theory are quite startling. It has come into existence as the result of an effort to determine our rate of motion, but it is absolutely an abstract, mathematical problem, and while it changes even our measurements, the change is so small as not to be discernible."

K. M. CHADWICK,
Secretary, Victoria Centre.

NOTES FROM THE METEOROLOGICAL SERVICE

NOVEMBER 1919

Temperature—The temperature was from 4° to 8° below the average in British Columbia, from 5° to 12° below in the Western Provinces, and 3° to 5° below in Northern Ontario, while from Southern Ontario to the Maritime Provinces the mean temperature deviated very little from the normal, some few localities being 1° above, while others were 1° below the average.

Precipitation—The precipitation exceeded the average in British Columbia by an amount varying from one to over two inches, except in a few localities on Vancouver Island, where, although the fall was fairly heavy, the normal for November was not quite reached. In the Western Provinces the normal, which for November is light, was exceeded, except locally in Manitoba. In Ontario the precipitation was below the average over the greater portion of the peninsula and near the north shore of Lake Ontario, and above the average in the Northern and Eastern parts of the province. In Quebec in the districts lying immediately north of the Ottawa River, also in the St. Lawrence basin between Montreal and Quebec the precipitation, which was somewhat over three inches, did not deviate much from the normal, but further north and between Quebec City and the mouth of the St. Lawrence it was quite light, being generally less than two inches in the latter area. In the western districts of the Maritime Provinces the precipitation was very heavy but in Prince Edward Island and Cape Breton it was a little below normal.

Depth of Snow on the Ground—At the close of the month Northern British Columbia had 10 inches of snow on the ground, and the Western Provinces were covered with an amount varying from 2 to 16 inches. Northern Ontario had from 2 to 8 inches, while elsewhere in Ontario, also in Quebec and the Maritime Provinces, a few traces were only locally recorded.

Thickness of Ice—Edmonton, 12 inches; Prince Albert, 6 inches; Battleford, 10 inches; The Pas, 12 inches; Minnedosa, 5 inches; Port Arthur, 5 inches.

TEMPERATURE FOR NOVEMBER, 1919

STATIONS	NOVEMBER		STATIONS	NOVEMBER	
	Highest	Lowest		Highest	Lowest
Yukon			*Ontario—continued*		
Dawson	12	−40	Huntsville	50	− 2
British Columbia			Kenora	43	−18
Atlin	—	—	Kinmount	—	—
Agassiz	53	25	Kingston	60	12
Barkerville	45	−13	Kitchener	61	15
Kamloops	59	1	London	59	17
New Westminster	57	26	Lucknow	59	8
Prince Rupert	58	24	Markdale	61	5
Vancouver	57	23	North Gower	53	− 1
Victoria	55	30	Oshawa	69	16
Western Provinces			Ottawa	59	7
Battleford	50	−28	Paris	65	18
Calgary	58	−12	Parry Sound	50	0
Edmonton	57	−39	Peterborough	64	5
Medicine Hat	59	−18	Port Arthur	48	− 8
Minnedosa	42	−22	Port Burwell	—	—
Moosejaw	54	−22	Port Dover	54	18
Oakbank	42	−25	Port Stanley	59	18
Portage la Prairie	—	—	Queensborough	54	3
Prince Albert	50	−24	Ronville	52	1
Qu'Appelle	46	−27	Southampton	56	12
Regina	—	—	Stonecliffe	52	− 8
Saskatoon	—	—	Stoney Creek	62	18
Souris	—	—	Toronto	64	16
Swift Current	56	−26	Uxbridge	51	8
Winnipeg	42	−18	Wallaceburg	60	19
Ontario			Welland	62	17
Agincourt	58	18	White River	48	−24
Aurora	53	8	*Quebec*		
Bancroft	52	− 1	Brome	54	2
Barrie	52	3	Father Point	48	9
Beatrice	56	− 2	Montreal	53	12
Bloomfield	65	11	Quebec	49	6
Brantford	59	18	Sherbrooke	52	2
Chapleau	40	−22	*Maritime Provinces*		
Chatham	58	20	Charlottetown	52	14
Clinton	65	15	Chatham	56	8
Collingwood	70	18	Dalhousie	—	—
Cottam	—	—	Fredericton	58	2
Georgetown	60	10	Halifax	58	20
Goderich	—	—	Moncton	—	—
Gravenhurst	53	4	St. John	—	—
Grimsby	69	18	Sussex	60	− 1
Guelph	63	15	Sydney	58	22
Haliburton	57	− 2	Yarmouth	58	22

EARTHQUAKE RECORDS BY MILNE SEISMOGRAPH, TORONTO.

SIR FREDERIC STUPART, F.R.S.C., DIRECTOR.

No.	Date 1919	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
2062	Nov. 1			5 58.1	5 59.7	6 07.3	0.2	Gradual thickening.
2063	" 6			7 27.8 to 7 33.6			0.1	
2064	" 6			7 39.1		7 45.1	0.1	
2065	" 18			4 31.3) 4 45.0)			0.05	
2066	" 18		22 14.8	22 24.5	22 41.6	23 42.9	1.3	P waves not defined.
2067	" 20			14 41.3) 14 58.2)			0.1	Small micros interfered with initial phases.
2068	" 20			15 15.0) 15 19.0)	15 24.2	16?03.0	0.8	Marked thickening 15:19 to 15:26.
2069	" 20			16 28.9		17 09.8	0.05	
2070	" 23			7 11.7	7 18.3	7 31.9	0.2	Gradual thickening.
2071	" 28			14 22.5	14 29.7	Micros.	0.1	Asia Minor. Micros interfered with definition of waves.

Period of Boom 18 seconds. Pillar inclination 1 mm = 0″.45.

VICTORIA, B.C.

F. NAPIER DENISON, SUPERINTENDENT.

No.	Date 1919	P. T. Comm.	S. Comm.	L. W. Comm.	Max.	End	Max. Amp.	Remarks
		h m s	h m s	h m s	h m s	h m s	mm.	
2056	Nov. 6	7?47 51			7 51 47	8 03 36	0.3	
2057	" 14	6?57 06		6 58 35	7 02 32	7 16 18	0.3	656?
2058	" 18	4 23 04	4 31 26	4 45 41	4 54 47	5 17 10	0.5	6860
2059	" 18	22?29 32	22 34 27	22 40 51	22 48 13	23 25 06	0.5	3170?
2060	" 20	14 24 15	14 27 52	14?34 05	14 37 32	15 25 14	0.4	2160
2061	" 20				16 43 56	17 00 40	0.2	
2062	" 23	6 23 31	6?30 24	6 38 16	6 46 38	7?09 45	0.4	5200?
2063	" 28	14?04 28			14 35 27		0.2	Asia Minor?

Period of Boom 18 seconds. Pillar inclination 1 mm = 0″.54.

P.T. = Preliminary Tremors. S. = Secondary Waves. L.W. = Large Waves. A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

BOOK REVIEWS

Relations Remarquables entre les Eléments du Système Solaire par Lucien Demozay. 144 pages, 57 fig. Paris: Gauthier-Villars, 1919. Paper, 12 frs.

In past years many attempts have been made to discover definite relations between the elements of the solar system, but with no great success, Bode's Law being the one outstanding example which has survived the test of time, and many think it is not a real "law" at all. But in this work we have a serious attempt to trace connections between almost all the sets of elements of the planets and their satellites, and though the author modestly refrains from dealing explicitly with questions of cosmogony, the results he reaches often suggest what must have been the course of development followed by the sun and planets from the nebulous to the present stage.

The subjects of the chapters are as follows:

I. Relation existing between the order of the satellites, the distances from their primaries and the periods of revolution about them.

II. Examination of the situation of the perihelia.

III. Relation between the distances of the planets from the sun and the inclinations of their axes.

IV. Relation between the values of the longitudes of perihelia of the planets and the inclinations of their axes.

V. Supposed primitive form of our nebula and its mode of possible displacement in space.

VI. Periods of the rotations of the planets.

VII. Examination of the eccentricity of their orbits.

VIII. Examination of the various possible modes of formation of spiral nebulae.

IX. General sketch of a possible evolution of our solar system.

X. Final conclusions.

From the above it will be seen that the programme of the author is an extensive and ambitious one and great thought and labour must have been devoted to the task.

It will be impossible to give an analysis of all the chapters but a short review may be attempted of the first. It extends to 30 pages, being the longest in the book. Applying Kepler's Third Law to a system composed of a planet and its satellites, he shows that the ratio of the cube of the distance to the square of the period is proportional to the density of the central body. Taking a to be the radius of the orbit, expressed in radii of the central body, and t the period in terrestrial years, numerical values of the ratio are obtained for the earth, Mars, Jupiter and Saturn, which, on dividing by a single factor, give results approximately equal to the densities of the planets. The author then finds that the planets can be arranged in three distinct classes, and that in the distribution of the bodies in space the determining factor was the distance and not the period of the body. Later on he says that starting out only from observations on the distribution of the distances we reach the result that one can consider the formation of our system as commencing by a separation of the primitive condensation into three rings, of which the densities differed and which might be thought of as somewhat analogous to the nodes of a vibratory motion which is propagated from the centre to the periphery.

The relations obtained are not usually reached by simple direct paths and do not carry conviction on their face; but they are interesting and must be taken into consideration in any serious attempt to form a theory of the evolution of our system.

C. A. CHANT.

ASTRONOMICAL NOTES

FROM THE UNIVERSITY OF CAMBRIDGE ANNUAL REPORT, 1919, SOLAR PHYSICS OBSERVATORY.

The results obtained in these investigations have suggested a theory, which both accounts for many of the more important phenomena of thunderstorms, and relates them to those of fine-weather atmospheric electricity and of terrestrial magnetism. This theory adopts the assumption which the phenomena of terrestrial magnetism are generally held to require, viz. that condiderable conductivity exists in the upper atmosphere; it further makes use of the existence of the great mobility, which, in accordance with the recent experiments of Wellisch and others, the carriers of negative electricity dragged out of this conducting layer would possess; and it also takes into account the effects at the ground of the electrical field of a thunder cloud or shower cloud. There appears to be no reason for assuming that the polarity of such clouds may not be of either sign. The theory accounts for the preponderance of positive lightning discharges, of positively charged rain and of negative potential gradients in showers.

The theory also accounts for the normal positive electrical potential gradient of fine weather regions.

According to the view adopted, thunder clouds and other clouds from which heavy rain is falling may be regarded as electrical generators by which electric currents are maintained between the earth and the conducting layer of the upper atmosphere; currents in the upward direction preponderating, on account of the great mobility of the carriers of negative electricity, and so maintaining the positive potential of the upper conducting layer and supplying the downward current in regions of fine weather.

The order of magnitude of the currents in thunderstorms, as indicated by the results of observations of lightning discharges, is such as to suggest the possibility of correlating the phenomena of atmospheric electricity with those of terrestrial magnetism.

The electric force produced in the upper atmosphere above a thunderstorm at the moment of the passage of a lightning discharge is generally great enough to be of importance not only as a source of ionisation but also as giving rise to cathode rays, positive rays, and X-rays; the potentials available being in fact sufficient for the production of corpuscular rays of very high velocity.

The theory does not conflict with existing theories of terrestrial magnetism which are based upon the arrival of corpuscular and other radiations from the sun. It rather affords a suggestion that processes similar to those existing in terrestrial thunderstorms may themselves be the source of origination of the emission of such radiations from the sun.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

QUERY.

Grand Forks. N.D. Dec 26/19.

Royal Astronomical Society.

Dear sir:-

A. Bets Haleys. Comet was going in a westerly direction.

B. Bets Haleys Comet was going in a Easterly direction.

I would be very much pleased if you could give me the ans. or what direction did it apear to be going to the naked eye. it apeared here in the spring of 1910.

Thanking you in advance for your ans.

Yours Truly

ANSWER.

The above query was thought of sufficient interest to be published in facsimile. Although I do not approve of betting I shall answer the question.

Halley's Comet was travelling westward in the sky until about April 20, 1910, when it turned and went eastward.

Apparently both *A* and *B* win.

DEATH OF DR. JULES CORNU.

Through Mr. Louis Gauthier, of the Geodetic Survey, I learn of the death of Dr. Jules Cornu, formerly a professor in the University of Graz and a member of various scientific societies. The death occurred at Leoben on November 27, 1919, in his seventy-first

year. On the outbreak of the war Dr. Cornu was obliged to go into exile in Switzerland on account of his writings against the Germans and their policy. Dr. Felix Cornu, of Ottawa, is a relative of the deceased.

Appointments of Canadian Scientists.

I am pleased to learn that the following members of the Meteorological Office, Toronto, have been appointed on committees of the International Geodetic and Geophysical Union, established in 1919 at Brussels by the International Research Council:—Sir Frederic Stupart, on the section of Meteorology; Mr. J. Patterson, M.A., on the joint committee on Atmospheric Electricity named by the sections of Meteorology and Terrestrial Magnetism; and Mr. W. E. W. Jackson, M.A., on the section of Terrestrial Magnetism and Electricity.

Error in the "Handbook"

On page 24 of the "Handbook" for 1920, it is stated that the distance of Mars from the earth on January 15 is 155 millions of miles. It should be 123 millions. C. A. C.

FOR SALE OR EXCHANGE

Harvard Annals

Vol. 11; Vol. 12; Vol. 13; Vols. 15-23 inc.; Vol. 41, parts 1, 3, 9; Vol. 42, parts 1, 2; Vol. 43; Vol. 48; Vol. 49; Vol. 51; Vol. 53; Vol. 56, parts 1, 2; Vol. 58; Vol. 60; Vol. 65; Vol. 68, part 1.

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